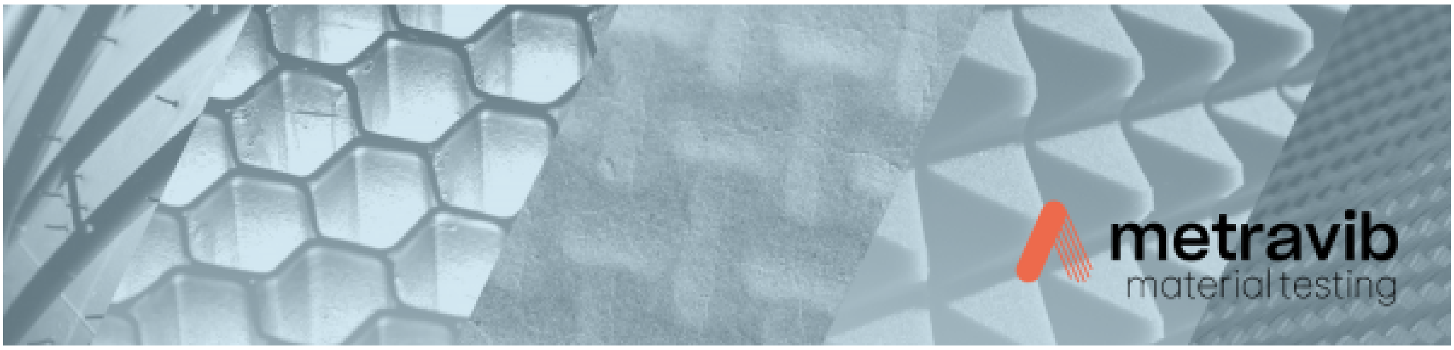


Viscoelastic Characterization of Foam - 10 KHz

Keywords: VHF104, Viscoelasticity, Foam, Resonance, High frequency testing

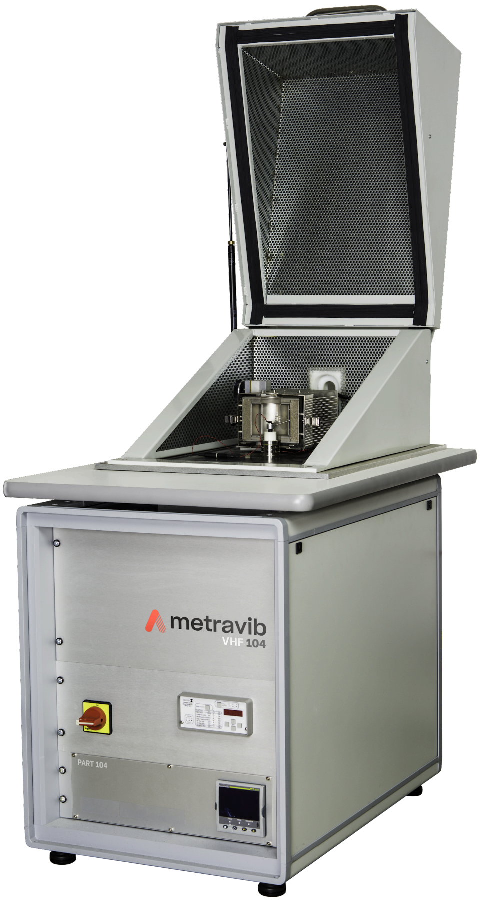


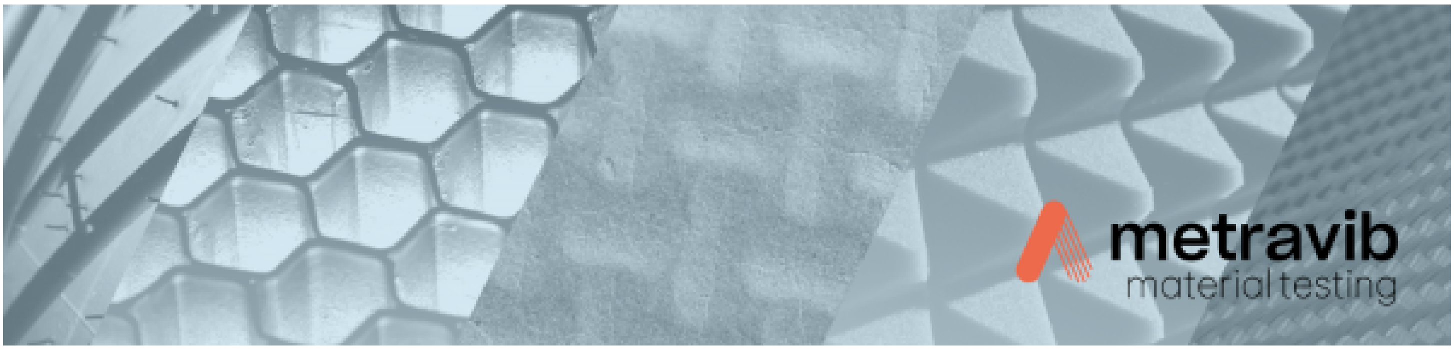
Figure 1. Metravib VHF104

Introduction

VHF104 is a unique and innovative Dynamic Mechanical Analyzer that applies a direct experimental method to measure the material viscoelastic properties over a very high frequency range from 100 Hz to 10 KHz. This high frequency material analysis takes a relatively short time period to complete the test.

Unlike common DMA tests, the aim here is to characterize a damped element close to a resonant analysis. A system “mass-spring” type is used (spring = specimen stiffness).

On the principle, an additional mass, chosen in relation to the resonance frequency of the mass-spring assembly, is glued on a cylindrical sample. On the top, an accelerometer-type sensor is glued on the additional mass (γ_m). This assembly is placed on the lower column of an electrodynamic shaker where a second accelerometer-type sensor is located (γ_e).



The electrodynamic shaker generates the required stress or deformation (generally low, less than 2% of deformation)

Figure 2 shows the overall arrangement of a VHF104 system.

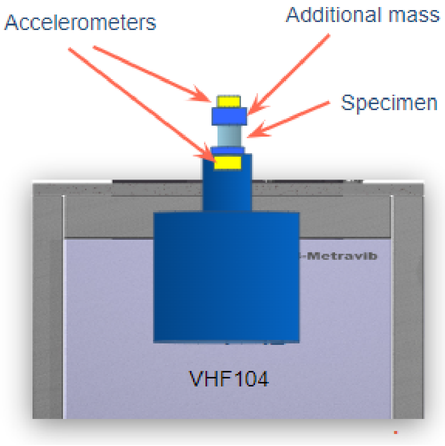


Figure 2. Functional diagram of VHF104

The modulus and the phase of the acceleration transmissibility function (γ_e/γ_m), which corresponds to a longitudinal excitation of the specimen, are measured at different frequencies.

The specimen's complex elasticity modulus is derived from the transmissibility function measured by identification with the transmissibility provided by a test configuration model.

Material and method

The material used for this study was Polyurethane (PU) foam. PU foam is a specialist material used for thermal insulation having application in several industrial applications such as automobile industry, aviation industry and structural applications.

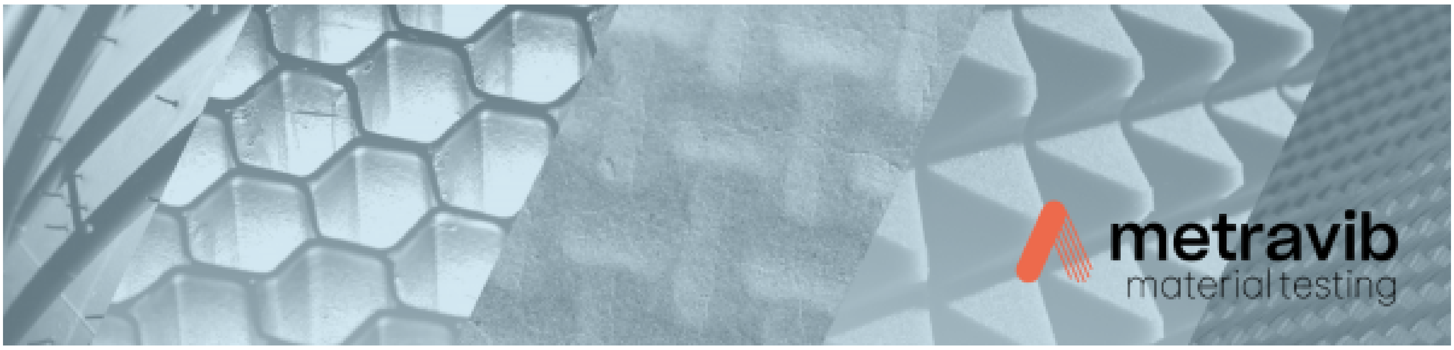
The cylindrical specimens used for this study were 10 mm in diameter along with 4 mm in height. These specimens were studied in tension-compression mode i.e., a mix mode. Since, the goal of this study was to identify the viscoelastic properties of PU foam at very high frequencies i.e., until 10 KHz, a frequency sweep (100 Hz to 10 KHz) was performed at three different temperatures. The liquid nitrogen is used as a cold source to go to low temperatures. The parameters used for the test are mentioned in Table 1.

Dynamic Strain	1e-5 (0,001%)
Frequency (Hz)	100 - 10000
Temperature (˚C)	-10, 10 and 20
Test Mode	Tension-compression

Table 1. Test parameters

The minimum frequency for testing is 100 Hz because below the frequency is not high enough and we measure the same acceleration between γ_e and γ_m.

The VHF104 measurements progresses in three stages:



1. Calibration of accelerometric measurement channels.

The purpose of this stage is to correct measured accelerations due to mounting imperfections and to the difference of behavior between the two accelerometers. The calibration measurement consists in performing a “standard“ measurement, replacing the viscoelastic specimen with a rigid element. The calibration configuration must be as representative as possible of the mass and geometry of the test configuration that will follow (with the viscoelastic specimen). This means that, to get better results, the calibration operation must be performed prior to each change to the test configuration.
The calibration operation allows correcting the measurements from deviations observed between the measured transfer function (in calibration mode) and the theoretical transfer function (modulus = 1 / phase = 0). The calibration operation is performed at room temperature.

2. Measurement of the transfer function.

This stage consists of measuring the transfer function between the two accelerometers and using it in the post-processing software. Transfer functions are measured using frequency sweeps on different temperature stages (min. -50°C; Max. +110°C). The excitation level can be controlled with:

- constant acceleration, or
- Constant deformation ratio, or
- constant dynamic displacement for the head mass, or
- constant dynamic displacement of the excitation table, within the operating limits of the electrodynamic shaker.

When the measurement is completed, measured transfer functions can be exported to determine the specimen’s dynamic characteristics using post-processing software VHFG.

3. Post-processing of the measurements.

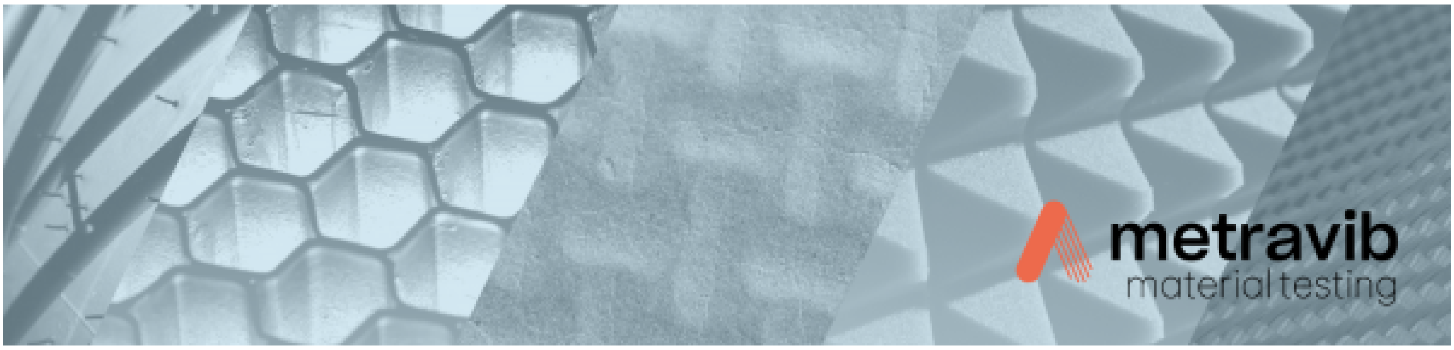
This final stage consists in reading the measured transfer function and deriving the specimen’s dynamic characteristics.

Specimen’s dynamic characteristics are determined based on the comparison of measured transfer functions with calculated transfer functions (in-situ finite element calculation). The calculated transfer function is determined from a modal superposition calculation.

Materials characteristics are identified frequency by frequency by searching for E and h values that minimize the difference between calculated transmissibility and measured transmissibility.

Results

Results obtained from VHF104 in terms of Acceleration transfer function modulus H and phase angle dH, are shown in Figure 3.



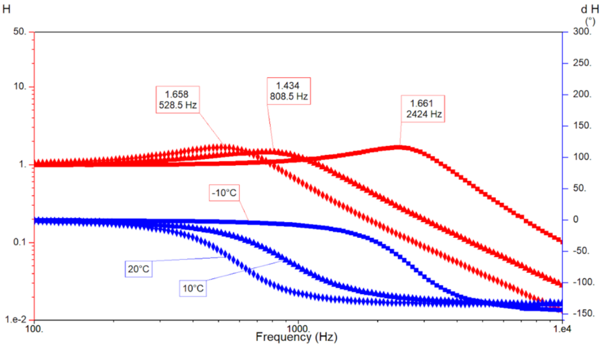


Figure 3. Acceleration transfer function modulus H and phase angle dH as a function of frequency at -10˚C, 10˚C and 20˚C.

Results derived after post-processing in terms of storage modulus E' and phase angle Tan delta, are shown in Figure 4.

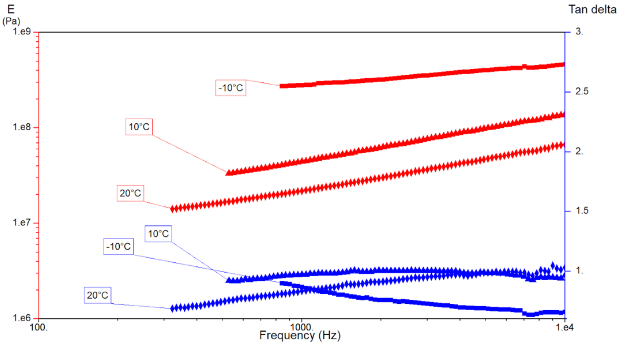


Figure 4. Derived storage modulus E' and Tan delta as a function of frequency at -10˚C, 10˚C and 20˚C.

Since, the resonance frequency of the mechanical system "specimen - additional mass" was observed to be in range of ~500 Hz and ~2400 Hz, the storage modulus (E') and Tan delta have been computed at each temperature between half of the resonance frequency and 10 KHz.

During these measurements, the temperature and frequency effect was observed from the results (see Figure 4) i.e., the storage modulus decreased with increasing effect and increased with increasing frequency.

Conclusions

This study shows the ability of Metravib VHF104 for characterization of viscoelastic properties of materials at very high frequencies.

Reaching 10KHz is impossible with standard DMA without computing master curves, which are based on a mathematical model allowing the viscoelastic extrapolation, but it requires around 6 hours of test with liquid nitrogen and by definition, these are calculated data.

One VHF104 measurement from 100 Hz to 10 KHz requires around 30 min and the user has direct and measured data. The characterization of materials at this magnitude of high frequencies could be interesting for industrial application of materials such as tire industry, shoe industry, aerospace industry etc.

PU foams were characterized at very high frequencies at three different temperatures. The temperature and frequency effect was observed on PU foams. The resonance frequency observed on PU foams specimens were found to be in between ~500 Hz and ~2400 Hz.

Authors: Pankaj YADAV | pankaj.yadav@acoem.com

More info: www.metravib-materialtesting.com